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Active Aging and Public Health: Evidence, Implications, and Opportunities

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Abstract

By 2050, 20% of the world's population will be over the age of 65 years, with projections that 80% of older adults will be living in low- to middle-income countries. Physical inactivity and sedentary time are particularly high in older adults, presenting unique public health challenges. In this article, we first review evidence that points to multiple beneficial outcomes of active aging, including better physical function, cognitive function, mental health, social health, and sleep, and we suggest the need to shift the research focus from chronic disease outcomes to more relevant

outcomes that affect independence and quality of life. Second, we review the critical role of age-friendly environments in facilitating active aging equitably across different countries and cultures. Finally, we consider emerging opportunities related to social engagement and technology-enabled mobility that can facilitate active aging. In all these contexts, it is a priority to understand and address diversity within the global aging population.

1. BACKGROUND

The prevalence of chronic diseases is increasing globally, with the highest observed in older adults, those over the age of 65 years (135). Active aging involving regular physical activity and avoidance of prolonged time spent sitting is associated with a reduced risk of premature mortality, morbidity, better management of chronic disease, and a higher quality of life. However, movement patterns among older adults remain suboptimal (106). The coronavirus disease 2019 (COVID-19) pandemic has exacerbated this problem; some studies suggest a decrease of 900–1,700 steps per day and an increase of 30 min of sitting per day (12). Calls for physical distancing and the increased risk of hospitalization and death from COVID-19 among older adults resulted in the closure of many activity-related programs (54), leading to increased physical inactivity, social isolation, and functional decline (58). Thus, now more than ever, the role of public health in encouraging an active lifestyle is critical for supporting healthy aging.

Contemporary evidence points to new and promising directions for research and public health initiatives that involve an integrated approach to physical activity and sedentary time (112). Further development of the evidence base required to inform public health policies, guidelines, and practices and to address equity issues relevant to older adults is critically needed in order to address sedentary time and its interrelationship with physical activity (25, 37, 43, 105). Here, we review the positive potential of active aging, emphasizing the importance of age-friendly environments, social engagement, and opportunities related to social engagement and technology across the full 24-hour day for older adults.

2. VARIATIONS IN ACTIVE AGING BETWEEN AND WITHIN SOCIETIES

In 2019, there were approximately 700 million older adults worldwide; this number is expected to double by 2050, and the number of older adults over the age of 80 is expected to triple by 2050 (131). The fastest growth as a proportion of the population is occurring in East and Southeast Asia, Latin America, and the Caribbean. While population aging is a global phenomenon, the life expectancy of older adults varies by socioeconomic status, health status, and region. For example, although life expectancy has improved in sub-Saharan Africa, the average life expectancy of 60.5 years is still 18 years below that of those living in North American and European countries (131).

The experiences of active aging within and between countries and cultures vary significantly. Cultural practices such as morning walks, tai chi, and yoga may be associated with higher levels of habitual physical activity among those living in India or China (11, 96), whereas cultural norms such as working past the age of 65 years may be associated with higher incidental or occupational levels of physical activity in those living in countries such as Norway, Iceland, Japan, and South Korea (103). Similarly, pervasive negative aging stereotypes, such as the belief that older adults are forgetful, frail, and weak or are unable to do intense activities, may limit engagement

in active living or may act to promote more sedentary time among older adults in Western countries (36).

Findings from 12 countries suggest that living in a low-income/high-deprivation area and a lack of safety within the community can serve as significant barriers to physical activity among older adults (56). Within high-income countries, older adults of middle and higher socioeconomic status have higher levels of physical activity participation (93), whereas among low-income countries, those in lower-income categories are more likely to be physically active (52). This contrasting evidence points to the importance of considering socioeconomic disadvantage in the context of countries and cultures for understanding and influencing active aging across the global population.

Lack of equity in active aging remains a fundamental concern within and between countries and intersects with gender, poverty, race/ethnicity, and social class. Physical activity security, that is, "[w]hen all people, at all times, have physical and economic access to sufficient, safe and enjoyable physical activity to meet, not only their health needs, but to promote physical and emotional well-being and social connectedness, for an active and healthy life" (86, p. 1448), is thus an essential goal to ensure implementation of policies and programs suitable for older adults across the globe. Below we highlight the importance of age-friendly environments, but it is critical to note that the availability of these environments, and their effects on different domains of activity (leisure versus occupational or incidental activity) will be dramatically different across subgroups of older adults. There is an immediate need for research evidence and a focus on inclusion in public policies and guidelines pertaining to active aging (62).

3. 24-HOUR MOVEMENT PATTERNS AND CONTEXT

3.1. Movement Patterns

Advances in measurement technology have been pivotal in helping to broaden the behavioral targets for the promotion of active aging (see Section 3.2) and have underscored the importance of addressing the full 24 hours (112). As shown in **Figure 1**, the fundamental distinction is between time spent sleeping and time spent in awake behaviors (129). For behaviors during waking hours, the enhanced granularity afforded through device-based measures has underpinned a contemporary perspective that classifies behaviors as either movement or nonmovement, with movement behaviors now occurring across a spectrum of intensity, ranging from light-intensity to vigorous-intensity activities.

Earlier public health approaches to active aging have typically emphasized moderate-to-vigorous physical activity (commonly referred to as exercise). However, reviews of the relevant evidence indicate significant benefits of resistance training or muscle strengthening activity (21% lower risk of all-cause mortality, very low quality of evidence) and balance and functional training (reduced fall rate, high quality of evidence) (44, 94). Among older adults who meet the guidelines for aerobic activity, participating in any strength training is associated with better balance, mobility, body composition, perceived health, and healthy aging (26). In contrast, high levels of sedentary behavior are unfavorably associated with multiple health outcomes (30, 114).

The World Health Organization (WHO) 2020 guidelines (16) on physical activity and sedentary behavior for older adults, those for the United Kingdom (119) and Australia (6), and also the Canadian 24-hour movement guidelines for older adults (112) emphasize addressing the key components of sedentary time, resistance/muscle strengthening activity, aerobic activity, and balance/functional activities. Such guidelines tend not to use the term exercise, despite exercise being what has been examined in some of the most robust evidence available. This preference is likely due to the importance of terminology and messaging in affecting behavior change (48). As the science

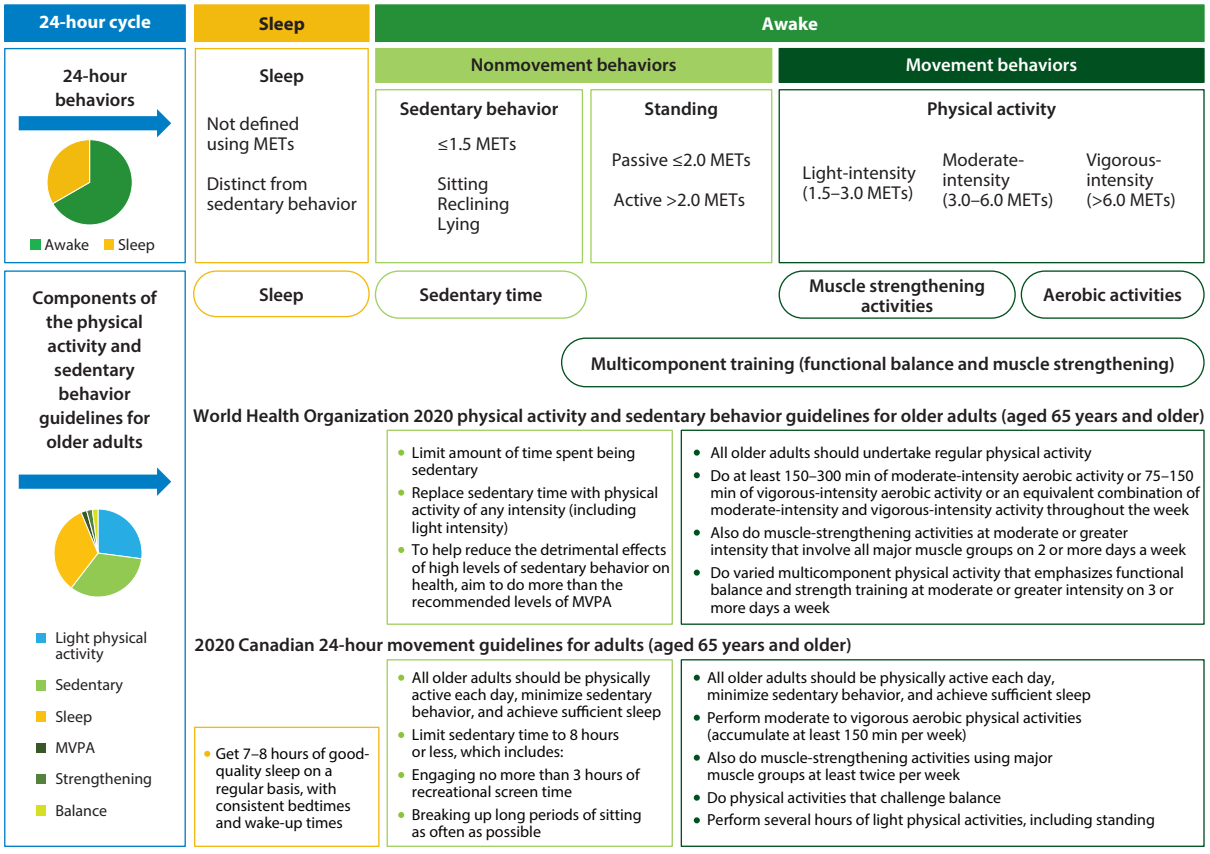

Figure 1

Active living opportunities for older adults in a 24-h cycle, showing (from *left* to *right*) 24-h behaviors first categorized as sleep (*yellow*) or awake (*green*); then, for awake behaviors as approximate METs for nonmovement (*light green*) and movement behaviors (*dark green*); finally, specific components of the 2020 World Health Organization physical activity and sedentary behavior guidelines and the 2020 Canadian 24-hour movement guidelines (both for adults aged 65 years and older; the World Health Organization guidelines do not include sleep). Sleep is defined as "a normal, reversible, recurrent state of reduced responsiveness to external stimulation that is accompanied by complex and predictable changes in physiology" (45). Abbreviations: METs, metabolic equivalents; MVPA, moderate-to-vigorous physical activity; PA, physical activity.

progresses, these guidelines will be subject to further refinements to identify quantifiable targets across the full movement behavior spectrum, including light-intensity physical activity and sit-to-stand transitions, for which promising evidence of favorable health benefits is beginning to emerge (38, 73, 85). It will also be critical to consider broader weekly patterns of behavior, as previous research suggests that an increase in physical activity volume or intensity on one day may lead to a compensatory decrease on the following days (55).

3.2. Context of Movement and Measurement

The 24-hour behaviors occur within different domains, that is, occupation, leisure, transport, and household; they have different dimensions, that is, frequency, intensity, time, and type; and they have different determinants, that is, where, why, and with whom. The complexity of the behaviors

and the contexts in which they occur provide challenges for measurement. Measures need to be valid, reliable, and sensitive to change. While self-report measures have been, and continue to be, used for cost and feasibility reasons, they are often subject to reporting errors related to social desirability bias (1), cognitive impairment (67), or comprehension (66).

Device-based measures have lower levels of variability when compared with self-report measures (41); nevertheless, human judgment is required in the use of devices, such as determining how study participants are briefed, adherence to device-wear protocols, the number of days of monitoring, or the definition of a valid day. The position (thigh, waist, wrist, other) and type (uniaxial/triaxial accelerometer, inclinometer) of device may also influence the estimates produced. As the cost of devices continues to decline, their inclusion in large population-based studies is growing. For example, a wrist-worn accelerometer was used to derive a phenotype representing overall activity type in more than 100,000 participants in the UK Biobank Study (39). Studies have also analyzed data from smartphone users; data from 717,527 people from 111 countries were used to analyze 68 million days of physical activity (number of steps) (2). While there is great promise in harnessing data from commercially available consumer devices, which can be inexpensive and accessible, critical analysis and a broader scientific consensus are needed to minimize misinterpretation of such big data evidence. Of note, there are currently no device-based assessments of resistance/muscle strengthening activity, balance/functional activities, or particular sedentary behaviors. To date, only small-scale studies have trialed the use of wearable cameras to capture activities and their context across the day (87). Thus, for the foreseeable future, self-report and device-based measures will need to continue to coexist.

In the future, high-quality device-based measurement is likely to deliver important new insights into the prevalence of and trends in active aging, particularly in the context of countries, cultures, and socioeconomic status. Available evidence indicates that adults from Southeast Asia appear to be the most active (approximately 70% meeting physical activity guidelines), followed by older adults from Africa, the Western Pacific, Europe, and the Eastern Mediterranean, with older adults from the Americas being the least active (less than 40% meeting guidelines) (59). While initiatives such as the Global Physical Activity Observatory provide country-level data on physical activity from more than 150 member countries, they often do not include data by age group, nor do they consistently include information related to strength or balance training. A more age-specific and complete approach to surveillance is needed.

4. ACTIVE AGING AND KEY HEALTH OUTCOMES

The prevalence of multimorbidity is ~95% in some populations of older adults (135). Nevertheless, older adults with chronic diseases report good perceived health (126), and perceived health appears to be more important than chronic disease for active aging (35). Thus, an approach that goes beyond the simple presence or absence of chronic disease can enrich perspectives on active aging and public health. Geriatricians use "geriatric syndromes," an approach that considers conditions such as frailty and falls, cognitive impairment, urinary incontinence, polypharmacy, and depressive symptoms (72), which is a measure of severity and/or impact of chronic conditions on quality of life and independence.

Here, we suggest that active aging research and public health initiatives should focus on physical function, cognitive function, mental health, social health, and sleep, which together provide a breadth of perspective that is less constrained by a focus on the prevention and management of particular chronic diseases (25, 37). This broader, multidisciplinary approach and its major components should allow for the creation of more inclusive and relevant research outputs and public health messages that facilitate active aging.

4.1. Physical Function

In later life, there is a population-wide transition from independence and adequate physical function toward frailty (24, 100, 104). Frailty and associated comorbidities compromise quality of life and contribute major societal costs to health and social care services (27, 82), both directly to people who live with frailty and to their family and caregivers. Frailty has been touted as "the new frontier of medicine" (33, p. 1384); many of its impacts make it a frontier for public health as well.

The prognosis for older adults with deteriorating physical function (indicated by poor lower limb physical function) can be bleak (42, 63). However, several observational studies and systematic reviews have highlighted the positive impact of exercise programs on physical function, independent living, falls, hospital admissions, and mortality. New evidence addressing methodological limitations such as small sample sizes, short duration of interventions, and lack of long-term follow-up (5, 28, 51) is promising. The US Lifestyle Interventions and Independence for Elders (LIFE) efficacy trial with 1,635 physically inactive men and women aged 70–89 with physical limitations showed that exercise can reduce the risk of developing major mobility disability (107). However, being an efficacy trial, the LIFE intervention was resource intensive, and there was no long-term follow-up. Preliminary data from the REtirement in ACTion (REACT) study showed that a low-resource, one-year exercise and behavior maintenance intervention improved physical functioning in community settings in the United Kingdom, with clinically meaningful benefits sustained over at least 24 months in older adults who were frail or prefrail (123, 124, 144). The REACT study provides important evidence that the trajectory of declining physical functioning with age is preventable and, importantly, may even be reversible.

This evidence base is particularly timely, given the decrease in physical condition during the COVID-19 pandemic. Maintaining independence and mobility in later life is critical for ensuring that older adults can age in place, an important consideration for quality of life in later years (143).

4.2. Cognitive Function

Declines in cognitive function range from mild cognitive impairment to dementia and confer large personal, social, and economic costs. The incidence rate for dementia has declined by 13% per decade over the past 25 years (145), but global aging is expected to cause an increase in cases. The number of people living with dementia increased from 20.2 million in 1990 to 43.8 million in 2016 (101). Up to 40% of dementia cases can be prevented or delayed; estimates show that a 2% reduction can be achieved if physical inactivity in later life were to be eliminated (92). Thus, the WHO guidelines on risk reduction of cognitive decline and dementia recommend physical activity for healthy adults and those with mild cognitive impairment (141).

In addition to the protective effect of total physical activity on the development of Alzheimer's disease (9), patterns of physical activity such as slow gait speed are significantly associated with an elevated risk of cognitive decline and dementia (109). Acute and long-term physical activity interventions lead to improved brain structure and function in older adults (46). An umbrella review reported that physical activity interventions have shown improvements in cognition in people with mild cognitive impairment and dementia and that resistance training interventions had a larger impact on global cognition than did mixed physical activity interventions (31). Recent trials focusing on reducing dementia risk have adopted a multidomain approach whereby researchers target physical activity as well as other lifestyle factors, such as diet, in conjunction with cognitive training, social engagement, and management of medical risk factors (79).

Observational studies suggest that higher levels of sedentary time are associated with poorer cognition (25, 47). However, it is unclear whether it is the sedentary time or the particular

behaviors while sedentary that are driving the association. For example, recent studies have designated some seated activities as mentally passive, e.g., watching television, and other activities as mentally active, e.g., reading (61). Nevertheless, decreasing sedentary time may improve some of the metabolic processes underlying cognitive decline such as glucose control and blood pressure (139). Taken together, the evidence suggests that some of the significant potential of active aging is in the prevention of cognitive impairment; experimental evidence is urgently needed to go beyond the limitations of observational findings to better support recommendations for sedentary time, strength training, and physical activity for both prevention and management of cognitive function.

4.3. Mental Health

Significant life changes associated with aging—such as declines in health, loss of family and friends, and financial pressure—as well as a loss of control can result in depression and anxiety. Both conditions are associated with significant comorbidity and decreases in quality of life (29, 75).

Physical activity can be protective against depression. Evidence on aerobic exercise, resistance training, and mind-body exercise (e.g., tai chi, fitness qigong, and yoga) from prospective and experimental studies is favorable (148). In fact, exercise can be an effective alternative to medication in treating depression in older people (148). Mentally passive sedentary behaviors have been associated with an increased risk of depression (70); however, more frequent interruptions to sedentary time have been found to be associated with lower odds of depression/anxiety symptoms (60). In addition, a recent meta-analysis reported that exercise leads to lower anxiety scores (75). Anxiety has been found to be associated with double the likelihood of being highly sedentary (eight hours per day or more compared with less than eight hours per day) (133). Promising evidence from four countries has suggested that replacing 30 min per day of sedentary time with light-intensity or moderate-intensity physical activity may improve anxiety symptoms (130).

The COVID-19 pandemic has exacerbated mental health problems across age groups. Findings from a recent cross-sectional study of 1,046 adults aged 50 years and older in North America suggest that even light-intensity physical activity may be sufficient to alleviate the negative mental health effects that older adults have experienced during the COVID-19 pandemic (18). Thus, the evidence on increasing physical activity and reducing or breaking up sedentary time in the prevention and management of anxiety and depression appears promising.

4.4. Social Health

A number of factors contribute to social health: the ability to form and engage in positive and meaningful relationships with others, the ability to adapt to different social settings, and the sense of belonging to a community. Among older adults, social engagement has been associated with a number of relevant health outcomes, including dental health, mental health, and dementia incidence (40). Social connections, social participation, and volunteering impact social support and social cohesion, which together significantly impact healthy aging (40).

Evidence indicates that these social constructs identify factors that are critical for active aging. For example, the English Longitudinal Study of Ageing showed that socially isolated participants reported higher volumes of sedentary behavior and less time engaging in physical activity (116); other evidence suggests that older adults who live on their own have less social support and are involved in less physical activity than are those who live with other people (147). A prospective cohort study with 311 older adults who were hospitalized found that improvements in physical function six months after release were associated with better social health measures, such as contact with relatives and reduced social isolation (111). Some sedentary activities, such as visiting others,

may provide important social benefits as they are associated with an improved sense of belonging to a community, satisfaction with life, and mental health outcomes in older adults (102).

Engaging in social activities leads to an increase in physical activity, and being physically active ensures the physical capability necessary to continue to be socially active. Thus, an emphasis on social components may facilitate physical activity engagement (83). Strategies to reduce sedentary behavior may require close consideration of the context in which sedentary time is accumulated, and the design of creative interventions should ensure that social activity is not compromised when reducing sitting time in older adults.

4.5. Sleep

Although sleep is a biological necessity and a key determinant of the ability to thrive and maintain general functioning and physical and mental health, insufficient sleep duration or poor sleep quality or both is widespread among older adults (99). Approximately 50% of older adults report having sleep problems, which exacerbate fatigue and daytime sleepiness and are adversely associated with multiple health outcomes and inactivity (95, 128). Both short and long sleep durations are associated with adverse health outcomes, including mortality, incident cardiovascular disease, incident type-2 diabetes, incident depression, and incident obesity (moderate to high-quality evidence) (21). Dose–response evidence indicates that 7–8 hours per night is the sleep duration most favorable for health outcomes; age does not modify this association. Sleep characteristics, such as later sleep timing and greater sleep variability, are generally associated with adverse health outcomes (22). Thus, sleep is a behavior that not only reflects underlying health conditions, but also has a bidirectional association with active aging.

Strong evidence indicates that both acute bouts of physical activity and lifestyle physical activity improve a variety of sleep outcomes in healthy adults, with generally consistent effects across age groups (81). In older adults, moderate-intensity exercise programs, with a frequency of 3 times per week and a duration of 12 weeks up to 6 months, have been shown to be the most efficacious for sleep outcomes (134). Nevertheless, prominent research gaps still remain in relation to the differential impacts of various types, intensities, doses, and patterns of both physical activity and sedentary behavior on sleep parameters in older adults. New perspectives from studies on associations of the composition of 24-hour movement behaviors with health suggest that if sleep duration is insufficient, benefits could occur if time was reallocated into sleep from sedentary time, but not if it was reallocated from physical activity, particularly moderate-to-vigorous intensity activity (74). Evidence is needed to better understand the effects of inadequate sleep on active aging outcomes and the impact of chronic comorbidities and polypharmacy.

4.6. Summary

For older adults, well-being is multidimensional and extends beyond physical health to include mental, social, developmental, and financial aspects (121). According to older adults, having something worthwhile to do, maintaining balance between abilities and challenges, having positive personal characteristics, and enlisting valuable external resources are key aspects of a meaningful life (13). The five health outcomes reviewed above highlight a growing body of evidence that includes observational and experimental findings, supporting the beneficial role of movement for overall quality of life in older adults (**Table 1**).

5. AGE-FRIENDLY ENVIRONMENTS AND POLICIES

Applying a social-ecological perspective to active aging, we propose four levels of influence. Individual factors, such as retirement or marital status, age, sex, gender, and socioeconomic status,

Table 1 Active aging and key health outcomes

Health outcome	Goal	Target
Physical function	Maintain independence and prevent frailty	Improve balance, strength, and mobility
Cognitive function	Prevent cognitive decline	Use multidomain approaches, physical activity, and resistance training
Mental health	Maintain resilience and sense of agency	Interrupt sedentary time, engage in light-intensity physical activity
Social health	Promote a sense of belonging and social engagement	Prioritize physical capability, physical activity with social components
Sleep	Increase daytime vigor	Engage in moderate-intensity physical activity, reallocate sedentary time

all influence whether an older adult engages in adequate levels of physical activity (120). In a study of six low-to-middle-income countries, age, employment, and household wealth were most consistently associated with meeting physical activity guidelines in adults aged 50 and older (52). However, in addition to these individual-level factors, neighborhood-level socioeconomic status can significantly impact health-related outcomes (17) and active aging (146). Thus, a broader environmental approach is needed.

Sociocultural factors, such as social support, age stereotypes, or cultural expectations, may limit or facilitate active aging. For example, a large epidemiological study of older adults in Europe indicated that loneliness was an independent risk factor for physical inactivity, as well as for relevant outcomes such as cognitive impairment (53). As discussed above, social engagement and physical activity are likely to be mutually related, particularly among retired older adults and older women (97). Positive expectations regarding aging are also significantly associated with engagement in physical activity (3, 36).

While efforts to increase physical activity levels in older adults have most often focused on individual-level behavior change (57), a growing body of evidence highlights the importance of contextual factors affecting behavioral choices (64). The characteristics of the built and natural environment in which older adults reside (Sections 5.1 and 5.2), such as access to destinations (stores and services), pedestrian and cycling infrastructure, safe crosswalks, and greenness, have been shown to be important determinants of physical activity (80). Recent research points to the impact of perceived environmental characteristics on active aging (108, 118), suggesting the need to examine the relevance of self-reported metrics when assessing the association between the environment and movement in older adults.

Finally, age-friendly policy can influence engagement in physical activity as well. For example, age-friendly municipalities may have regulations, guidelines, and programs that prioritize the needs of older adults, such as subsidizing physical activity programming or maintaining places where individuals can visit and interact (e.g., parks with amenities and facilities).

Responding to evidence that the mainstream urban design and planning principles do not explicitly incorporate older adults' needs and concerns (15), the WHO published a guide in 2008 for age-friendly cities that focused on eight dimensions (140). It has since put forward a more comprehensive approach on creating age-friendly environments that includes a focus on combating ageism, enabling autonomy, and supporting healthy aging in policies at all levels (142). This guidance aligns with lessons learned from *The Blue Zones*, which describes how the vast majority of centenarians engage in movements in nature or simply have an active lifestyle that includes incidental physical activity related to household work (14).

5.1. Built Environment Evidence from Community-Dwelling Older Adults

The body of evidence on the ways in which neighborhood environmental attributes may influence physical activity is rapidly growing (132). These attributes include a range of factors, such as the proximity of destinations relevant to older adults, safe routes for walking or bicycle use, and perceptions of neighborhood safety.

Designing age-friendly communities requires careful consideration of the variability in functional capacities present in older populations (20). Personal and interpersonal determinants such as maintenance of good health, functional ability, and supportive social networks are critical for supporting active aging (122). In particular, opportunities for physically active transport can be a key to maintaining regular habits of active living. Several environmental attributes have been identified in this context (19, 80). These include higher levels of residential density and street connectivity, convenience of access to services and destinations, greater variety in local land uses, and pedestrian-friendly street design, all of which can be key elements of neighborhood walkability. Thus, city planning strategies such as "the 15-minute city" can enhance age-friendliness (98). Much of the available evidence, however, is from cross-sectional studies (19). A prospective study examining the role of environmental attributes found that higher perceived levels of proximity, a larger number of utilitarian destinations, better street connectivity, and higher quality of walking paths were associated with more positive changes in frequency of walking for transport (127). Further prospective studies (e.g., natural experiments examining the effects of environmental modification or residential relocation) need to identify the kinds of destinations that will be most important for encouraging active transport and how these might vary by country, culture, socioeconomic status, and degree of urbanization (7, 19).

5.2. Built Environment Evidence from Those in Assisted Living Environments

Assisted living can be defined as residences for older adults that offer supportive living environments to ensure that residents can maintain independence. These are distinct from nursing homes or long-term care, as the support offered is not medical in nature (113). Thus, assisted living should be considered in public health initiatives.

While individual factors certainly play a role in activity levels of older adults in assisted living, many environmental-level factors contribute to inactivity. In a qualitative study of 31 older adults in assisted living in Canada, several environmental barriers to decreasing sedentary time were identified. These included a lack of activities outside of business hours, safety concerns, and social norms (137). This finding is in line with research on physical activity that suggests that gender, cognitive and mental health, social support, and satisfaction with staff and activities were determinants of physical activity levels among 171 residents studied at four assisted living homes (69). When a multicomponent intervention developed using a social-ecological approach was implemented in assisted living with the intent of reducing prolonged sitting time, older adults with lower physical function showed clinically meaningful improvements after six weeks (136). Similarly, in a 12-month cluster randomized controlled trial conducted with older adults in assisted living, a multicomponent physical activity program that included a staff champion, environmental changes, and individualized goals led to changes in functional decline and ambulatory status. That the greatest improvements were seen toward the end of the 12-month program was attributed to the changes related to policy and practice taking longer to implement (110).

As age-friendly environments continue to be developed, we need to consider inequities; otherwise, environmental interventions may exacerbate disparities and reduce active aging in some, while facilitating it in others (**Figure 2**).

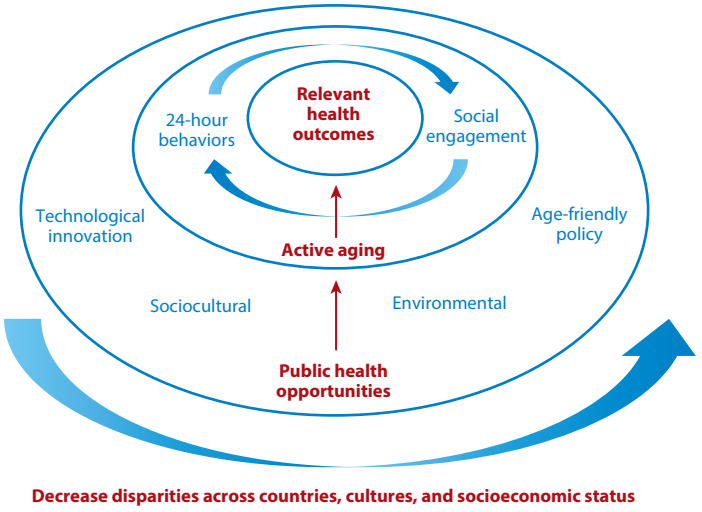

Figure 2

An ecological perspective addresses a broad-based population health approach to active aging, although individual factors should also be considered in the implementation and evaluation of such approaches. The influence of active aging on relevant health outcomes requires consideration of 24-h behaviors and social engagement. There are several public health opportunities to facilitate active aging; however, caution is needed to ensure that such initiatives do not further exacerbate disparities across countries, cultures, and socially disadvantaged groups.

6. IMPLICATIONS AND EMERGING OPPORTUNITIES

To look to the future, we focus on two major opportunities that have the capacity to spark change in active aging research and the development of age-friendly public health policies and programs. It is important to note, however, that these opportunities are accompanied by a great challenge, that is, ensuring equity and inclusion. Increasing active aging among those of higher socioeconomic status alone should not simply be considered a victory, as it exacerbates existing inequities in health. Programming and policies need to ensure that older adults across cultural and socioeconomic backgrounds are able to increase their daily movement. While some nations and organizations are aware of this challenge, and have created plans to address such inequities (62, 65), many are still focused on recreation or leisure physical activity alone, which will further "privileg[e] the privileged" (125). It is thus the responsibility of researchers to provide details about recruitment processes, sample characteristics, efforts to be inclusive of diverse older adults, and results by different sociodemographic characteristics. Transparency is needed in how programming, policies, and research prioritize equity and inclusion.

6.1. Social Engagement

Physical distancing due to the COVID-19 pandemic has negatively affected the physical and mental health of older adults (117); however, the issue of social engagement was one of significant concern even prior to the pandemic. More walkable neighborhoods are associated with better social health (90), pointing to a significant opportunity for active aging: creating a "third place" in neighborhoods where older adults can visit and interact with neighbors.

Third places are public or commercial places where people can gather (71). Such places can be particularly important for retired older adults who do not have opportunities to socialize at work.

For example, a study in the United States found that third places were a significant predictor of social support and social connectedness (88). In an innovative study conducted in Japan, community salons (i.e., hubs) intended to provide opportunities for social interaction among older residents found a 6.3% lower incidence in functional disability (68). This association may be at least partially mediated by physical activity such that social participation facilitates physical activity (84), and physical activity reduces the risk of geriatric-relevant health outcomes. While local parks (7) and higher amounts of perceived green space are associated with better social health (76), evidence suggests that the number of establishments that can serve as a third place has been declining (49). Research on third places is still in its infancy: Little is known about the types and attributes of third places that can facilitate social interactions and active aging. Clearly, the built environment can influence mobility in the community, which can influence social engagement (77). Future research is needed to carefully investigate the effects of environmental-level interventions on social participation and active aging, with some consideration directed to the effects of intergenerational interactions in such spaces (89) and to the influence of countries, cultures, and the socioeconomic status of older adults.

6.2. Technology-Enabled Mobility

Technology offers several opportunities for enhancing the mobility of older adults. First, a shift away from cars to shared or public transport and active travel or electric-assisted micromobility may be invaluable for ensuring autonomy. While car use is the predominant mode of travel in many countries, many older adults stop driving owing to the loss of ability to drive safely (4). This limitation on driving has negative impacts on well-being and social engagement (23). In addition to the conventional modes of travel (i.e., private motor vehicles, public transit), there are now diverse ways to move within a city, including car sharing, bicycle sharing, ride sharing, and on-demand transport (34). However, adequate infrastructure and age-friendly policies are needed to facilitate active travel, as they have in some parts of the world (32). For example, in the Netherlands, the CycleOn program aims to educate older adults on safety with local community partners (138). Technology related to micromobility, particularly pedal assist electric bikes (e-bikes), shows great promise. Such e-bikes require pedaling, but motor assistance is available for longer distances, hilly terrain, or windy days. Research has shown that the use of an e-bike is still considered of sufficient intensity to be classified as light or moderate physical activity (10) and that e-bike riders tend to be older (50).

Second, wearable devices have been used with great success in motivating older adults to sit less and move more (91); however, controlled trials are needed to better understand the potential benefits. A promising approach is to harness technology in the form of mobile applications and citizen science. The Our Voice program of research has conducted 14 projects with older adults across 5 continents to work effectively with local stakeholders to enact meaningful environmental and policy changes that can help to promote healthy aging (78). For example, they developed an age-friendly "golden path" walking map in Haifa, Israel (78, p. 7). Similarly, information technology and wearable devices can be an integral part of urban mobility (115). Such approaches can provide insight into the movement of older adults who live in different regions, countries, and cultures, allowing researchers to better understand the determinants of physical activity and sedentary time across diverse groups of older adults. That local knowledge can facilitate the design and implementation of targeted and more effective activity initiatives that are tailored to the needs and opportunities of specific environmental and socioeconomic contexts.

Last, innovations under the rubric of smart cities and smart homes can be leveraged to collect relevant data on movement patterns to better understand the types of interventions with potential

PUBLIC HEALTH OPPORTUNITIES FOR ACTIVE AGING

- Identify and overcome barriers to participation that result from social inequalities.
- Create third spaces, that is, places where people spend time between home (first place) and work (second place) in local communities, and promote intergenerational initiatives.
- Implement technology to enable mobility and independence.
- Promote age-friendly and inclusive policies to facilitate active aging in communities.

and to facilitate movement by providing real-time support. As with the two aforementioned opportunities, this approach may be relevant only to those in higher-income countries. For example, SmartWalk was designed to promote walking in older adults by collecting data from different sensors in smart cities and providing information to caregivers to help plan routes (8). New technologies are emerging regularly; thus, it is on researchers in the area of active aging to collaborate across disciplinary siloes to ensure that the most-effective interventions and age-friendly environments are being created.

The sidebar titled Public Health Opportunities for Active Aging summarizes several dimensions of social engagement as well as rapidly emerging options for technology-enabled mobility.

7. CONCLUSIONS

Our goal has been to provide a perspective on recent evidence relating to the beneficial effects of active aging and to highlight emerging ideas and opportunities for novel public health initiatives. Several opportunities are apparent. First, we need to think more broadly about how we define older adults, considering the differences in life expectancy, the diversity of the aging experience, and the inequities across different countries and cultures. Second, evidence supports broadening the focus from physical activity and exercise to include sedentary behavior and to consider a wider range of outcomes relevant to health and quality of life. Third, while individual behavior change continues to be a target for active aging strategies, environmental and policy-focused initiatives will be important for broad-based health benefits. Fourth, new and emerging social and technological opportunities can be leveraged to facilitate active aging. Finally, in order to promote active aging at a population level, we particularly need to take into account the physical and socioeconomic heterogeneity of our aging population to develop inclusive, equitable, and relevant approaches to active living for all older adults. Environmental, social, and economic equity between and within countries will fundamentally determine older persons' opportunities for healthy and active aging. Innovative public health research that incorporates interdisciplinary approaches will create a more robust body of evidence that can be applied to a broader population base of older adults. The future of this field may also depend on the impacts of climate change; it is now time to start considering this critical intersection with active aging research.

SUMMARY POINTS

1. A more inclusive definition of aging incorporating a global perspective is needed.
2. Opportunities for active aging across the full 24 hours need to be highlighted in public health messages.

3. A greater emphasis needs to be placed on outcomes related to autonomy and quality of life.
4. Evidence suggests a need to shift the focus from individual behavior change to environmental-level interventions.
5. Social engagement may be critical for supporting 24-hour movement.

DISCLOSURE STATEMENT

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AUTHOR CONTRIBUTIONS

All the authors researched the data for the article, provided substantial contributions to discussions of its content, wrote the article, and undertook review and/or editing of the manuscript before submission.

LITERATURE CITED

1. Adams SA, Matthews CE, Ebbeling CB, Moore CG, Cunningham JE, et al. 2005. The effect of social desirability and social approval on self-reports of physical activity. *Am. J. Epidemiol.* 161:389–98
2. Althoff T, Sosič R, Hicks JL, King AC, Delp SL, Leskovec J. 2017. Large-scale physical activity data reveal worldwide activity inequality. *Nature* 547:336–39
3. Andrews RM, Tan EJ, Varma VR, Rebok GW, Romani WA, et al. 2017. Positive aging expectations are associated with physical activity among urban-dwelling older adults. *Gerontologist* 57:S178–86
4. Anstey KJ, Li X, Hosking DE, Eramudugolla R. 2017. The epidemiology of driving in later life: sociodemographic, health and functional characteristics, predictors of incident cessation, and driving expectations. *Accid. Anal. Prev.* 107:110–16
5. Apóstolo J, Cooke R, Bobrowicz-Campos E, Santana S, Marcucci M, et al. 2018. Effectiveness of interventions to prevent pre-frailty and frailty progression in older adults: a systematic review. *JBI Database Syst. Rev. Implement. Rep.* 16:140–232
6. Aust. Gov. Dep. Health. 2014. *Australia's physical activity and sedentary behaviour guidelines*. Fact Sheet Adults (18–64 years), Aust. Gov., Canberra. **https://www.health.gov.au/sites/default/files/documents/2021/09/physical-activity-and-sedentary-behaviour-guidelines-adults-18-to-64-years-fact-sheet_0.pdf**
7. Barnett DW, Barnett A, Nathan A, Van Cauwenberg J, Cerin E. 2017. Built environmental correlates of older adults' total physical activity and walking: a systematic review and meta-analysis. *Int. J. Behav. Nutr. Phys. Act.* 14:103
8. Bastos D, Ribeiro J, Silva F, Rodrigues M, Silva AG, et al. 2021. SmartWalk BAN: using body area networks to encourage older adults to perform physical activity. *Electronics* 10:56
9. Beckett MW, Ardern CI, Rotondi MA. 2015. A meta-analysis of prospective studies on the role of physical activity and the prevention of Alzheimer's disease in older adults. *BMC Geriatr.* 15:9
10. Berntsen S, Malnes L, Langåker A, Bere E. 2017. Physical activity when riding an electric assisted bicycle. *Int. J. Behav. Nutr. Phys. Act.* 14:55
11. Birdee GS, Cai H, Xiang Y-B, Yang G, Li H, et al. 2013. *T'ai chi* as exercise among middle-aged and elderly Chinese in urban China. *J. Altern. Complement. Med.* 19:550–57
12. Browne RAV, Macêdo GAD, Cabral LLP, Oliveira GTA, Vivas A, et al. 2020. Initial impact of the COVID-19 pandemic on physical activity and sedentary behavior in hypertensive older adults: an accelerometer-based analysis. *Exp. Gerontol.* 142:111121

13. Bryant LL, Corbett KK, Kutner JS. 2001. In their own words: a model of healthy aging. *Soc. Sci. Med.* 53:927–41
14. Buettner D. 2012. *The Blue Zones: 9 Lessons for Living Longer from the People Who've Lived the Longest*. Washington, DC: Natl. Geogr. Books. 2nd ed.
15. Buffel T, Phillipson C. 2016. Can global cities be 'age-friendly cities'? Urban development and ageing populations. *Cities* 55:94–100
16. Bull FC, Al-Ansari SS, Biddle S, Borodulin K, Buman MP, et al. 2020. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br. J. Sports Med.* 54:1451–62
17. Cain CL, Wallace SP, Ponce NA. 2018. Helpfulness, trust, and safety of neighborhoods: social capital, household income, and self-reported health of older adults. *Gerontologist* 58:4–14
18. Callow DD, Arnold-Nedimala NA, Jordan LS, Pena GS, Won J, et al. 2020. The mental health benefits of physical activity in older adults survive the COVID-19 pandemic. *Am. J. Geriatr. Psychiatry* 28:1046–57
19. Cerin E, Nathan A, van Cauwenberg J, Barnett DW, Barnett A. 2017. The neighbourhood physical environment and active travel in older adults: a systematic review and meta-analysis. *Int. J. Behav. Nutr. Phys. Act.* 14:15
20. Cerin E, Van Dyck D, Zhang CJP, Van Cauwenberg J, Lai P-C, Barnett A. 2020. Urban environments and objectively-assessed physical activity and sedentary time in older Belgian and Chinese community dwellers: potential pathways of influence and the moderating role of physical function. *Int. J. Behav. Nutr. Phys. Act.* 17:73
21. Chaput J-P, Dutil C, Featherstone R, Ross R, Giangregorio L, et al. 2020. Sleep duration and health in adults: an overview of systematic reviews. *Appl. Physiol. Nutr. Metab.* 45:S218–S31
22. Chaput J-P, Dutil C, Featherstone R, Ross R, Giangregorio L, et al. 2020. Sleep timing, sleep consistency, and health in adults: a systematic review. *Appl. Physiol. Nutr. Metab.* 45:S232–S47
23. Chihuri S, Mielenz TJ, DiMaggio CJ, Betz ME, DiGuiseppi C, et al. 2016. Driving cessation and health outcomes in older adults. *J. Am. Geriatr. Soc.* 64:332–41
24. Clegg A, Young J, Iliffe S, Rikkert MO, Rockwood K. 2013. Frailty in elderly people. *Lancet* 381:752–62
25. Copeland JL, Ashe MC, Biddle SJ, Brown WJ, Buman MP, et al. 2017. Sedentary time in older adults: a critical review of measurement, associations with health, and interventions. *Br. J. Sports Med.* 51:1539
26. Copeland JL, Good J, Dogra S. 2019. Strength training is associated with better functional fitness and perceived healthy aging among physically active older adults: a cross-sectional analysis of the Canadian Longitudinal Study on Aging. *Aging Clin. Exp. Res.* 31:1257–63
27. Craig R, Fuller E, Mindell J. 2015. *Health Survey for England, 2014: Health, social care and lifestyles*. Rep., NatCen Soc. Res., London
28. de Labra C, Guimaraes-Pinheiro C, Maseda A, Lorenzo T, Millán-Calenti JC. 2015. Effects of physical exercise interventions in frail older adults: a systematic review of randomized controlled trials. *BMC Geriatr.* 15:154
29. Demakakos P, Pierce MB, Hardy R. 2010. Depressive symptoms and risk of type 2 diabetes in a national sample of middle-aged and older adults: the English Longitudinal Study of Aging. *Diabetes Care* 33:792–97
30. Dempsey PC, Biddle SJH, Buman MP, Chastin S, Ekelund U, et al. 2020. New global guidelines on sedentary behaviour and health for adults: broadening the behavioural targets. *Int. J. Behav. Nutr. Phys. Act.* 17:151
31. Demurtas J, Schoene D, Torbahn G, Marengoni A, Grande G, et al. 2020. Physical activity and exercise in mild cognitive impairment and dementia: an umbrella review of intervention and observational studies. *J. Am. Med. Dir. Assoc.* 21:1415–22.e6
32. den Hoed W, Jarvis H. 2021. Normalising cycling mobilities: an age-friendly approach to cycling in the Netherlands. *Appl. Mobil.* **https://doi.org/10.1080/23800127.2021.1872206**
33. Dent E, Martin FC, Bergman H, Woo J, Romero-Ortuno R, Walston JD. 2019. Management of frailty: opportunities, challenges, and future directions. *Lancet* 394:1376–86
34. Dep. Transp., Cent. Connect. Auton. Veh., Rt Hon Jesse Norman MP. 2019. *Future of mobility: urban strategy*. Writ. Statement, March 19. **https://www.gov.uk/government/speeches/future-of-mobility-urban-strategy**

35. Dogra S. 2011. Better self-perceived health is associated with lower odds of physical inactivity in older adults with chronic disease. *J. Aging Phys. Act.* 19:322–35
36. Dogra S, Al-Sahab B, Manson J, Tamim H. 2015. Aging expectations are associated with physical activity and health among older adults of low socioeconomic status. *J. Aging Phys. Act.* 23:180–86
37. Dogra S, Ashe MC, Biddle SJ, Brown WJ, Buman MP, et al. 2017. Sedentary time in older men and women: an international consensus statement and research priorities. *Br. J. Sports Med.* 51:1526–32
38. Dogra S, Clarke JM, Copeland JL. 2017. Prolonged sedentary time and physical fitness among Canadian men and women aged 60 to 69. *Health Rep.* 28:3–9
39. Doherty A, Jackson D, Hammerla N, Plötz T, Olivier P, et al. 2017. Large scale population assessment of physical activity using wrist worn accelerometers: the UK Biobank Study. *PLOS ONE* 12:e0169649
40. Douglas H, Georgiou A, Westbrook J. 2017. Social participation as an indicator of successful aging: an overview of concepts and their associations with health. *Aust. Health Rev.* 41:455–62
41. Dowd KP, Szeklicki R, Minetto MA, Murphy MH, Polito A, et al. 2018. A systematic literature review of reviews on techniques for physical activity measurement in adults: a DEDIPAC study. *Int. J. Behav. Nutr. Phys. Act.* 15:15
42. Dugravot A, Fayosse A, Dumurgier J, Bouillon K, Rayana TB, et al. 2020. Social inequalities in multimorbidity, frailty, disability, and transitions to mortality: a 24-year follow-up of the Whitehall II cohort study. *Lancet Public Health* 5:e42–50
43. Dunstan DW, Dogra S, Carter SE, Owen N. 2021. Sit less and move more for cardiovascular health: emerging insights and opportunities. *Nat. Rev. Cardiol.* 18:637–48
44. El-Kotob R, Ponzano M, Chaput J-P, Janssen I, Kho ME, et al. 2020. Resistance training and health in adults: an overview of systematic reviews. *Appl. Physiol. Nutr. Metab.* 45:S165–79
45. Ellenbogen JM. 2021. Sleep. *Brittanica*. **https://www.britannica.com/science/sleep**
46. Erickson KI, Hillman C, Stillman CM, Ballard RM, Bloodgood B, et al. 2019. Physical activity, cognition, and brain outcomes: a review of the 2018 physical activity guidelines. *Med. Sci. Sports Exerc.* 51:1242–51
47. Falck RS, Davis JC, Liu-Ambrose T. 2017. What is the association between sedentary behaviour and cognitive function? A systematic review. *Br. J. Sports Med.* 51:800–11
48. Faught E, Walters AJ, Latimer-Cheung AE, Faulkner G, Jones R, et al. 2020. Optimal messaging of the Canadian 24-Hour Movement Guidelines for Adults aged 18–64 years and Adults aged 65 years and older. *Appl. Physiol. Nutr. Metab.* 45:S125–50
49. Finlay J, Esposito M, Kim MH, Gomez-Lopez I, Clarke P. 2019. Closure of 'third places'? Exploring potential consequences for collective health and wellbeing. *Health Place* 60:102225
50. Fishman E, Cherry C. 2016. E-bikes in the mainstream: reviewing a decade of research. *Transp. Rev.* 36:72–91
51. Frost R, Belk C, Jovicic A, Ricciardi F, Kharicha K, et al. 2017. Health promotion interventions for community-dwelling older people with mild or pre-frailty: a systematic review and meta-analysis. *BMC Geriatr.* 17:157
52. Gaskin CJ, Orellana L. 2018. Factors associated with physical activity and sedentary behavior in older adults from six low- and middle-income countries. *Int. J. Environ. Res. Public Health* 15:908
53. Giné-Garriga M, Jerez-Roig J, Coll-Planas L, Skelton DA, Inzitari M, et al. 2021. Is loneliness a predictor of the modern geriatric giants? Analysis from the survey of health, ageing, and retirement in Europe. *Maturitas* 144:93–101
54. Goethals L, Barth N, Guyot J, Hupin D, Celarier T, Bongue B. 2020. Impact of home quarantine on physical activity among older adults living at home during the COVID-19 pandemic: qualitative interview study. *JMIR Aging* 3:e19007
55. Goncin N, Linares A, Lloyd M, Dogra S. 2020. Does sedentary time increase in older adults in the days following participation in intense exercise? *Aging Clin. Exp. Res.* 32:2517–27
56. Gough C, Weber H, George S, Maeder A, Lewis L. 2021. Location monitoring of physical activity and participation in community dwelling older people: a scoping review. *Disabil. Rehabil.* 43:270–83
57. Grande GD, Oliveira CB, Morelhão PK, Sherrington C, Tiedemann A, et al. 2020. Interventions promoting physical activity among older adults: a systematic review and meta-analysis. *Gerontologist* 60:e583–99

37. Discusses a Delphi consensus on measurement, health outcomes, intervention, and knowledge priorities for sedentary time and aging.

43. Provides insights into physiological mechanisms, inter-relationship between physical activity and sedentary time, and counseling approaches.

48. Uses stakeholder feedback to develop understandable, confidence-building messaging related to 24-hour movement guidelines.

58. Hall G, Laddu DR, Phillips SA, Lavie CJ, Arena R. 2021. A tale of two pandemics: How will COVID-19 and global trends in physical inactivity and sedentary behavior affect one another? *Prog. Cardiovasc. Dis.* 64:108–10
59. Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, et al. 2012. Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet* 380:247–57
60. Hallgren M, Nguyen T-T-D, Owen N, Vancampfort D, Smith L, et al. 2020. Associations of interruptions to leisure-time sedentary behaviour with symptoms of depression and anxiety. *Transl. Psychiatry* 10:128
61. Hallgren M, Owen N, Stubbs B, Zeebari Z, Vancampfort D, et al. 2018. Passive and mentally-active sedentary behaviors and incident major depressive disorder: a 13-year cohort study. *J. Affect. Disord.* 241:579–85
62. Hämäläinen R-M, Sandu P, Syed AM, Jakobsen MW. 2016. An evaluation of equity and equality in physical activity policies in four European countries. *Int. J. Equity Health* 15:191
63. Hanlon P, Nicholl BI, Jani BD, Lee D, McQueenie R, Mair FS. 2018. Frailty and pre-frailty in middle-aged and older adults and its association with multimorbidity and mortality: a prospective analysis of 493 737 UK Biobank participants. *Lancet Public Health* 3:e323–32
64. Haselwandter EM, Corcoran MP, Folta SC, Hyatt R, Fenton M, Nelson ME. 2015. The built environment, physical activity, and aging in the United States: a state of the science review. *J. Aging Phys. Act.* 23:323–29
65. Hasson RE, Brown DR, Dorn J, Barkley L, Torgan C, et al. 2017. Achieving equity in physical activity participation: ACSM experience and next steps. *Med. Sci. Sports Exerc.* 49:848–58
66. Heesch KC, van Uffelen JG, Hill RL, Brown WJ. 2010. What do IPAQ questions mean to older adults? Lessons from cognitive interviews. *Int. J. Behav. Nutr. Phys. Act.* 7:35
67. Herbolsheimer F, Riepe MW, Peter R. 2018. Cognitive function and the agreement between self-reported and accelerometer-accessed physical activity. *BMC Geriatr.* 18:56
68. Hikichi H, Kondo N, Kondo K, Aida J, Takeda T, Kawachi I. 2015. Effect of a community intervention programme promoting social interactions on functional disability prevention for older adults: propensity score matching and instrumental variable analyses, JAGES Taketoyo study. *J. Epidemiol. Community Health* 69:905–10
69. Holmes SD, Galik E, Resnick B. 2017. Factors that influence physical activity among residents in assisted living. *J. Gerontol. Soc. Work* 60:120–37
70. Huang Y, Li L, Gan Y, Wang C, Jiang H, et al. 2020. Sedentary behaviors and risk of depression: a meta-analysis of prospective studies. *Transl. Psychiatry* 10:26
71. Hummon DM. 1991. The Great Good Place: Cafes, Coffee Shops, Community Centers, Beauty Parlors, General Stores, Bars, Hangouts, and How They Get You Through the Day. By Ray Oldenburg (book review). *Soc. Forces* 69:931–32
72. Inouye SK, Studenski S, Tinetti ME, Kuchel GA. 2007. Geriatric syndromes: clinical, research, and policy implications of a core geriatric concept. *J. Am. Geriatr. Soc.* 55:780–91
73. Jain P, Bellettiere J, Glass N, LaMonte MJ, Di C, et al. 2021. The relationship of accelerometer-assessed standing time with and without ambulation and mortality: the WHI OPACH study. *J. Gerontol. Ser. A* 76:77–84
74. Janssen I, Clarke AE, Carson V, Chaput J-P, Giangregorio LM, et al. 2020. A systematic review of compositional data analysis studies examining associations between sleep, sedentary behaviour, and physical activity with health outcomes in adults. *Appl. Physiol. Nutr. Metab.* 45:S248–57
75. Kazeminia M, Salari N, Vaisi-Raygani A, Jalali R, Abdi A, et al. 2020. The effect of exercise on anxiety in the elderly worldwide: a systematic review and meta-analysis. *Health Qual. Life Outcomes* 18:363
76. Kemperman A, Timmermans H. 2014. Green spaces in the direct living environment and social contacts of the aging population. *Landscape Urban Plan.* 129:44–54
77. Kikuchi H, Inoue S, Fukushima N, Takamiya T, Odagiri Y, et al. 2017. Social participation among older adults not engaged in full- or part-time work is associated with more physical activity and less sedentary time. *Geriatr. Gerontol. Int.* 17:1921–27

68. Reports that access to third places in communities leads to reduced risk of functional disability.

78. King AC, King DK, Banchoff A, Solomonov S, Ben Natan O, et al. 2020. Employing participatory citizen science methods to promote age-friendly environments worldwide. *Int. J. Environ. Res. Public Health* 17:1541

79. Kivipelto M, Mangialasche F, Snyder HM, Allegri R, Andrieu S, et al. 2020. World-Wide FINGERS Network: a global approach to risk reduction and prevention of dementia. *Alzheimer's Dement.* 16:1078–94

80. Klicnik I, Dogra S. 2019. Perspectives on active transportation in a mid-sized age-friendly city: "You stay home." *Int. J. Environ. Res. Public Health* 16:4916

81. Kline CE, Hillman CH, Sheppard BB, Tennant B, Conroy DE, et al. 2021. Physical activity and sleep: an updated umbrella review of the 2018 Physical Activity Guidelines Advisory Committee report. *Sleep Med. Rev.* 58:101489

82. Kojima G. 2019. Increased healthcare costs associated with frailty among community-dwelling older people: a systematic review and meta-analysis. *Arch. Gerontol. Geriatr.* 84:103898

83. Kosteli M-C, Williams SE, Cumming J. 2016. Investigating the psychosocial determinants of physical activity in older adults: a qualitative approach. *Psychol. Health* 31:730–49

84. Kubota A, Carver A, Sugiyama T. 2020. Associations of local social engagement and environmental attributes with walking and sitting among Japanese older adults. *J. Aging Phys. Act.* 28:187–93

85. LaCroix AZ, Bellettiere J, Rillamas-Sun E, Di C, Evenson KR, et al. 2019. Association of light physical activity measured by accelerometry and incidence of coronary heart disease and cardiovascular disease in older women. *JAMA Netw. Open* 2:e190419

86. Lambert EV, Kolbe-Alexander T, Adlakha D, Oyeyemi A, Anokye NK, et al. 2020. Making the case for 'physical activity security': the 2020 WHO guidelines on physical activity and sedentary behaviour from a Global South perspective. *Br. J. Sports Med.* 54:1447–48

87. Leask CF, Harvey JA, Skelton DA, Chastin SFM. 2015. Exploring the context of sedentary behaviour in older adults (what, where, why, when and with whom). *Eur. Rev. Aging Phys. Act.* 12:4

88. Lee JH, Tan TH. 2019. Neighborhood walkability or third places? Determinants of social support and loneliness among older adults. *J. Plan. Educ. Res.* **https://doi.org/10.1177/0739456X19870295**

89. Lee K, Jarrott SE, Juckett LA. 2020. Documented outcomes for older adults in intergenerational programming: a scoping review. *J. Intergen. Relationsh.* 18:113–38

90. Leyden KM. 2003. Social capital and the built environment: the importance of walkable neighborhoods. *Am. J. Public Health* 93:1546–51

91. Liu JY-W, Kor PP-K, Chan CP-Y, Kwan RY-C, Sze-Ki D. 2020. The effectiveness of a wearable activity tracker (WAT)-based intervention to improve physical activity levels in sedentary older adults: a systematic review and meta-analysis. *Arch. Gerontol. Geriatr.* 91:104211

92. Livingston G, Huntley J, Sommerlad A, Ames D, Ballard C, et al. 2020. Dementia prevention, intervention, and care: 2020 report of the Lancet Commission. *Lancet* 396:413–46

93. Manz K, Mensink GB, Jordan S, Schienkiewitz A, Krug S, Finger JD. 2018. Predictors of physical activity among older adults in Germany: a nationwide cohort study. *BMJ Open* 8:e021940

94. McLaughlin EC, El-Kotob R, Chaput J-P, Janssen I, Kho ME, et al. 2020. Balance and functional training and health in adults: an overview of systematic reviews. *Appl. Physiol. Nutr. Metab.* 45:S180–96

95. Miner B, Kryger MH. 2020. Sleep in the aging population. *Sleep Med. Clin.* 15:311–18

96. Mishra AS, Sk R, HS V, Nagarathna R, Anand A, et al. 2020. Knowledge, attitude, and practice of yoga in rural and urban India, KAPY 2017: a nationwide cluster sample survey. *Medicines* 7:8

97. Mobily KE, Smith AK, Chmielewski K. 2017. Work, retirement and working out: the construction of exercise and the social world of retired women. *Ann. Leis. Res.* 20:273–94

98. Moreno C, Allam Z, Chabaud D, Gall C, Pratlong F. 2021. Introducing the "15-minute city": sustainability, resilience and place identity in future post-pandemic cities. *Smart Cities* 4:93–111

99. Neikrug AB, Ancoli-Israel S. 2010. Sleep disorders in the older adult—a mini-review. *Gerontology* 56:181–89

100. Nguyen QD, Wu C, Odden MC, Kim DH. 2019. Multimorbidity patterns, frailty, and survival in community-dwelling older adults. *J. Gerontol. Ser. A* 74:1265–70

78. Discusses older adults as environmental change agents and mobile technology to facilitate active aging.

85. Found that accelerometer data indicated reduced risk of CVD in older women with light-intensity physical activity.

101. Nichols E, Szoeke CEI, Vollset SE, Abbasi N, Abd-Allah F, et al. 2019. Global, regional, and national burden of Alzheimer's disease and other dementias, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet Neurol.* 18:88–106
102. O'Neill C, Dogra S. 2016. Different types of sedentary activities and their association with perceived health and wellness among middle-aged and older adults: a cross-sectional analysis. *Am. J. Health Promot.* 30:314–22
103. OECD. 2011. Pensionable age and life expectancy, 1950–2050. In *Pensions at a Glance 2011. Retirement-Income Systems in OECD and G20 Countries*, pp. 19–38. Paris: OECD. **https://doi.org/10.1787/pension_glance-2011-en**
104. Osborne B, Cooper V. 2018. *Health Survey for England 2017: adult health related behaviours*. Rep., NHS Digit., Richmond, Surrey, UK
105. Owen N, Healy GN, Dempsey PC, Salmon J, Timperio A, et al. 2020. Sedentary behavior and public health: integrating the evidence and identifying potential solutions. *Annu. Rev. Public Health* 41:265–87
106. Ozemek C, Lavie CJ, Rognmo Ø. 2019. Global physical activity levels—need for intervention. *Prog. Cardiovasc. Dis.* 62:102–7
107. Pahor M, Guralnik JM, Ambrosius WT, Blair S, Bonds DE, et al. 2014. Effect of structured physical activity on prevention of major mobility disability in older adults: the LIFE study randomized clinical trial. *JAMA* 311:2387–96
108. Portegijs E, Keskinen KE, Tsai L-T, Rantanen T, Rantakokko M. 2017. Physical limitations, walkability, perceived environmental facilitators and physical activity of older adults in Finland. *Int. J. Environ. Res. Public Health* 14:333
109. Quan M, Xun P, Chen C, Wen J, Wang Y, et al. 2017. Walking pace and the risk of cognitive decline and dementia in elderly populations: a meta-analysis of prospective cohort studies. *J. Gerontol. Ser. A* 72:266–70
110. Resnick B, Galik E, Gruber-Baldini A, Zimmerman S. 2011. Testing the effect of function-focused care in assisted living. *J. Am. Geriatr. Soc.* 59:2233–40
111. Robins LM, Brown T, Lalor AF, Stolwyk R, McDermott F, Haines T. 2018. Social isolation, physical capacity and physical activity in older community-dwelling adults post-hospitalisation. *J. Aging Phys. Act.* 26:204–13
112. Ross R, Chaput J-P, Giangregorio LM, Janssen I, Saunders TJ, et al. 2020. *Canadian 24-Hour Movement Guidelines for Adults Aged 18–64 Years and Adults Aged 65 Years or Older: An Integration of Physical Activity, Sedentary Behaviour, and Sleep*. *Appl. Physiol. Nutr. Metab.* 45:S57–102
113. Sanford AM, Orrell M, Tolson D, Abbatecola AM, Arai H, et al. 2015. An international definition for "nursing home." *J. Am. Med. Dir. Assoc.* 16:181–84
114. Saunders TJ, McIsaac T, Douillette K, Gaulton N, Hunter S, et al. 2020. Sedentary behaviour and health in adults: an overview of systematic reviews. *Appl. Physiol. Nutr. Metab.* 45:S197–217
115. Schikofsky J, Dannewald T, Kowald M. 2020. Exploring motivational mechanisms behind the intention to adopt mobility as a service (MaaS): insights from Germany. *Transp. Res. A Policy Pract.* 131:296–312
116. Schrempft S, Jackowska M, Hamer M, Steptoe A. 2019. Associations between social isolation, loneliness, and objective physical activity in older men and women. *BMC Public Health* 19:74
117. Sepúlveda-Loyola W, Rodríguez-Sánchez I, Pérez-Rodríguez P, Ganz F, Torralba R, et al. 2020. Impact of social isolation due to COVID-19 on health in older people: mental and physical effects and recommendations. *J. Nutr. Health Aging*. **https://doi.org/10.1007/s12603-020-1469-2**
118. Shibata A, Oka K, Sugiyama T, Ding D, Salmon J, et al. 2015. Perceived neighbourhood environmental attributes and prospective changes in TV viewing time among older Australian adults. *Int. J. Behav. Nutr. Phys. Act.* 12:50
119. Skelton DA, Copeland RJ, Tew GA, Mavroeidi A, Cleather DJ, et al. 2018. *UK physical activity guidelines: review and recommendations for older adults (aged 65+ years)*. Expert Work. Group Work. Pap., Univ. Bristol, Bristol, UK. **http://www.bristol.ac.uk/media-library/sites/sps/documents/cmo/older-adults-technical-report.pdf**

105. Offers a comprehensive review of health consequences and workplace and school-based solutions for sedentary behavior.

112. Discusses the development process of the first integrated 24-hour movement guidelines for adults.

120. Smith L, Gardner B, Fisher A, Hamer M. 2015. Patterns and correlates of physical activity behaviour over 10 years in older adults: prospective analyses from the English Longitudinal Study of Ageing. *BMJ Open* 5:e007423
121. Stathi A, Fox KR, McKenna J. 2002. Physical activity and dimensions of subjective well-being in older adults. *J. Aging Phys. Act.* 10:76–92
122. Stathi A, Gilbert H, Fox KR, Coulson J, Davis M, Thompson JL. 2012. Determinants of neighborhood activity of adults age 70 and over: a mixed-methods study. *J. Aging Phys. Act.* 20:148–70
123. Stathi A, Withall J, Greaves C, Thompson J, Taylor G, et al. 2021. A randomised controlled trial and economic evaluation of a community-based physical activity intervention to prevent mobility-related disability in older adults: The REACT [REtirement in ACTion] study. *Public Health Res*. In press

124. Found that a physical activity intervention improved physical functioning, sustained over 24 months in frail or prefrail older adults.

124. Stathi A, Withall J, Greaves CJ, Thompson JL, Taylor G, et al. 2018. A community-based physical activity intervention to prevent mobility-related disability for retired older people (REtirement in ACTion (REACT)): study protocol for a randomised controlled trial. *Trials* 19:228
125. Straker L, Holtermann A, Lee I-M, van der Beek AJ, Stamatakis E. 2021. Privileging the privileged: the public health focus on leisure time physical activity has contributed to widening socioeconomic inequalities in health. *Br. J. Sports Med.* 55:7–8
126. Strawbridge WJ, Wallhagen MI, Cohen RD. 2002. Successful aging and well-being: self-rated compared with Rowe and Kahn. *Gerontologist* 42:727–33
127. Sugiyama T, Cerin E, Mridha M, Koohsari MJ, Owen N. 2018. Prospective associations of local destinations and routes with middle-to-older aged adults' walking. *Gerontologist* 58:121–29
128. Suzuki K, Miyamoto M, Hirata K. 2017. Sleep disorders in the elderly: diagnosis and management. *J. Gen. Fam. Med.* 18:61–71
129. Tremblay MS, Aubert S, Barnes JD, Saunders TJ, Carson V, et al. 2017. Sedentary Behavior Research Network (SBRN)–terminology consensus project process and outcome. *Int. J. Behav. Nutr. Phys. Act.* 14:75
130. Tully MA, McMullan I, Blackburn NE, Wilson JJ, Bunting B, et al. 2020. Sedentary behavior, physical activity, and mental health in older adults: an isotemporal substitution model. *Scand. J. Med. Sci. Sports* 30:1957–65
131. UN, Dep. Econ. Soc. Aff. 2020. World population ageing 2019. ST/ESA/SER. A/444, UN, New York
132. Van Cauwenberg J, Nathan A, Barnett A, Barnett DW, Cerin E. 2018. Relationships between neighbourhood physical environmental attributes and older adults' leisure-time physical activity: a systematic review and meta-analysis. *Sports Med.* 48:1635–60
133. Vancampfort D, Stubbs B, Herring MP, Hallgren M, Koyanagi A. 2018. Sedentary behavior and anxiety: association and influential factors among 42,469 community-dwelling adults in six low- and middle-income countries. *Gen. Hosp. Psychiatry* 50:26–32
134. Vanderlinden J, Boen F, van Uffelen J. 2020. Effects of physical activity programs on sleep outcomes in older adults: a systematic review. *Int. J. Behav. Nutr. Phys. Act.* 17:11
135. Violan C, Foguet-Boreu Q, Flores-Mateo G, Salisbury C, Blom J, et al. 2014. Prevalence, determinants and patterns of multimorbidity in primary care: a systematic review of observational studies. *PLOS ONE* 9:e102149

136. Innovative social-ecological multi-level intervention focused on reducing sitting may delay functional decline.

136. Voss M, Pope JP, Larouche R, Copeland JL. 2020. Stand When You Can: development and pilot testing of an intervention to reduce sedentary time in assisted living. *BMC Geriatr*. 20:277
137. Voss ML, Pope JP, Copeland JL. 2020. Reducing sedentary time among older adults in assisted living: perceptions, barriers, and motivators. *Int. J. Environ. Res. Public Health* 17:717
138. Wendel-Vos W, van den Berg S, Giesbers H, Harms L, Kruize H, Staatsen B . 2018. *Cycling in the Netherlands*. Fact Sheet, Natl. Inst. Public Health Environ., Bilthoven., Neth. **https://crowplatform.com/wp-content/uploads/Cycling-in-the-netherlands.pdf**
139. Wheeler MJ, Dempsey PC, Grace MS, Ellis KA, Gardiner PA, et al. 2017. Sedentary behavior as a risk factor for cognitive decline? A focus on the influence of glycemic control in brain health. *Alzheimer's Dement*. 3:291–300
140. WHO (World Health Organ.). 2007. *Global age-friendly cities: a guide*. Rep. 978 92 4 154730 7, WHO, Geneva. **https://www.who.int/ageing/publications/Global_age_friendly_cities_Guide_English.pdf**

141. WHO (World Health Organ.). 2019. *Risk reduction of cognitive decline and dementia: WHO guidelines*. Rep., WHO, Geneva. **https://www.who.int/publications/i/item/risk-reduction-of-cognitive-decline-and-dementia**
142. WHO (World Health Organ.). 2021. Age-friendly environments. *World Health Organization*. **https://www.who.int/teams/social-determinants-of-health/demographic-change-and-healthy-ageing/age-friendly-environments**
143. Wiles JL, Leibing A, Guberman N, Reeve J, Allen RES. 2012. The meaning of "aging in place" to older people. *Gerontologist* 52:357–66
144. Withall J, Greaves CJ, Thompson JL, de Koning JL, Bollen JC, et al. 2020. The tribulations of trials: lessons learnt recruiting 777 older adults into REtirement in ACTion (REACT), a trial of a community, group-based active aging intervention targeting mobility disability. *J. Gerontol. Ser. A* 75:2387–95
145. Wolters FJ, Chibnik LB, Waziry R, Anderson R, Berr C, et al. 2020. Twenty-seven-year time trends in dementia incidence in Europe and the United States: the Alzheimer Cohorts Consortium. *Neurology* 95:e519–31
146. Xiao Q, Keadle SK, Berrigan D, Matthews CE. 2018. A prospective investigation of neighborhood socioeconomic deprivation and physical activity and sedentary behavior in older adults. *Prev. Med.* 111:14–20
147. Yu C-Y, Hou S-I, Miller J. 2018. Health for older adults: the role of social capital and leisure-time physical activity by living arrangements. *J. Phys. Act. Health* 15:150–58
148. Zhang S, Xiang K, Li S, Pan H-F. 2021. Physical activity and depression in older adults: the knowns and unknowns. *Psychiatry Res.* 297:113738

RELATED RESOURCES

CSEP (Can. Soc. Exerc. Physiol.). 2021. Canadian 24 hour movement guidelines for adults ages 65 and older. *CSEP*. **https://csepguidelines.ca/adults-65/**

WHO (World Health Organ.). 2020. *World Health Organization guidelines for physical activity and sedentary behavior*. Rep., WHO, Geneva. **https://www.who.int/publications/i/item/9789240015128**

WHO (World Health Organ.). 2021. Age-friendly environments. *WHO Global Network for Age-Friendly Cities and Communities*. **https://www.who.int/teams/social-determinants-of-health/demographic-change-and-healthy-ageing/age-friendly-environments**

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